Asbestos Exposure During and Following Cable Installation In the Vicinity of Fireproofing

William M. Ewing,[A] Jean Chesson,[B] Tod A. Dawson,[A]
Eva M. Ewing,[A] Richard L. Hatfield,[C] Steve M. Hays,[D]
Dale L. Keyes,[E] William E. Longo,[F] James R. Millette[G]
and William H. Spain[A]

A study was conducted to determine whether installing cables above a suspended tile ceiling where a low-density asbestos-containing fireproofing was present on the structural beams and decking would result in elevated airborne concentrations of asbestos. The study was designed to simulate routine cable installation and cleaning typical of that used by service workers when they are unaware of the presence of asbestos. Personal and area air sampling was conducted before, during and after the installation of 12 cables. Personal and area air sampling was also conducted during cleaning activities approximately two hours after the cable installation. All samples and blanks were analyzed by transmission electron microscopy (TEM) using an indirect preparation technique. Results are reported as asbestos structures per cubic centimeter of air (s/cm^3).

The geometric mean of area samples collected prior to cable installation was 0.002 s/cm^3. The mean of area samples collected during the cable installation was 3.5 s/cm^3 and the mean of personal samples was 26 s/cm^3. Area sampling conducted during a period following completion of the cable installation averaged 3.4 s/cm^3. Airborne asbestos during the clean-up phase of the study averaged 55 s/cm^3 (area samples) and 44 s/cm^3 (personal samples). All of the increases in asbestos concentrations were statistically significant when compared to levels measured before the work began.

The results demonstrated a significant increase in airborne asbestos concentrations during and immediately following cable installation activities compared to concentrations before cable installation. The results also demonstrate a significant increase in airborne asbestos concentrations during routine cleaning activities.

Introduction and Background

The presence of friable asbestos-containing materials (ACM) in buildings is of interest due to the potential for exposure of building occupants and workers to asbestos fibers.(1) Asbestos exposures fall into two categories: prevalent level exposures and episodic exposures.(2) Episodic exposures frequently result from custodial or maintenance activities which directly disturb in-place ACM or dust and debris derived from these materials.(1-6) For service workers who routinely work in the vicinity of ACM, episodic events may characterize their prevalent exposure.

Service workers who perform custodial and maintenance tasks in buildings with friable ACM have been shown to be at greater risk of exposure and disease.(5,7-12) Only a few studies, however, have been conducted to determine what level of exposures occur during tasks that service workers perform.(11-16) Accordingly, a series of experiments were designed and conducted to gather additional data to help characterize these exposures. This article reports on one of these experiments.

One common activity which occurs in office buildings is the installation of cables and wiring for communications and electrical service. In buildings with suspended ceilings, cables and wires are often installed above the suspended ceiling systems. Exposure to airborne asbestos may occur when asbestos-containing fireproofing is present above the suspended ceiling and when dust and/or debris from the fireproofing is present on the ceiling tiles.

A related study previously investigated whether installing cable in a ceiling plenum where asbestos-containing fireproofing was present results in elevated airborne asbestos concentrations.(14) The results of that study indicated a 500-fold increase during the work activities with several samples exceeding 50 asbestos structures per cubic centimeter (s/cm^3) as measured with transmission electron microscopy (TEM). This previous study was performed in a school building with fireproofing containing approximately 10-12 % chrysotile asbestos (by weight) in a gypsum and vermiculite matrix.

The purpose of the present study was to determine whether similar results are obtained with a different type of asbestos-containing fireproofing. The previous study involved a wet-applied high-density material. The current study involved a lower density material composed of approximately 25-30 % (by weight) chrysotile asbestos in a mineral wool (60%), cement (2%), and bentonite (3%) matrix. The study was designed to evaluate the methods historically used by service workers installing cable or used today by individuals either not aware that asbestos-containing materials are present or unwilling to take proper precautions. Despite the attention given to asbestos in recent years, we have found that the failure to take precautions when working around ACM is not uncommon.

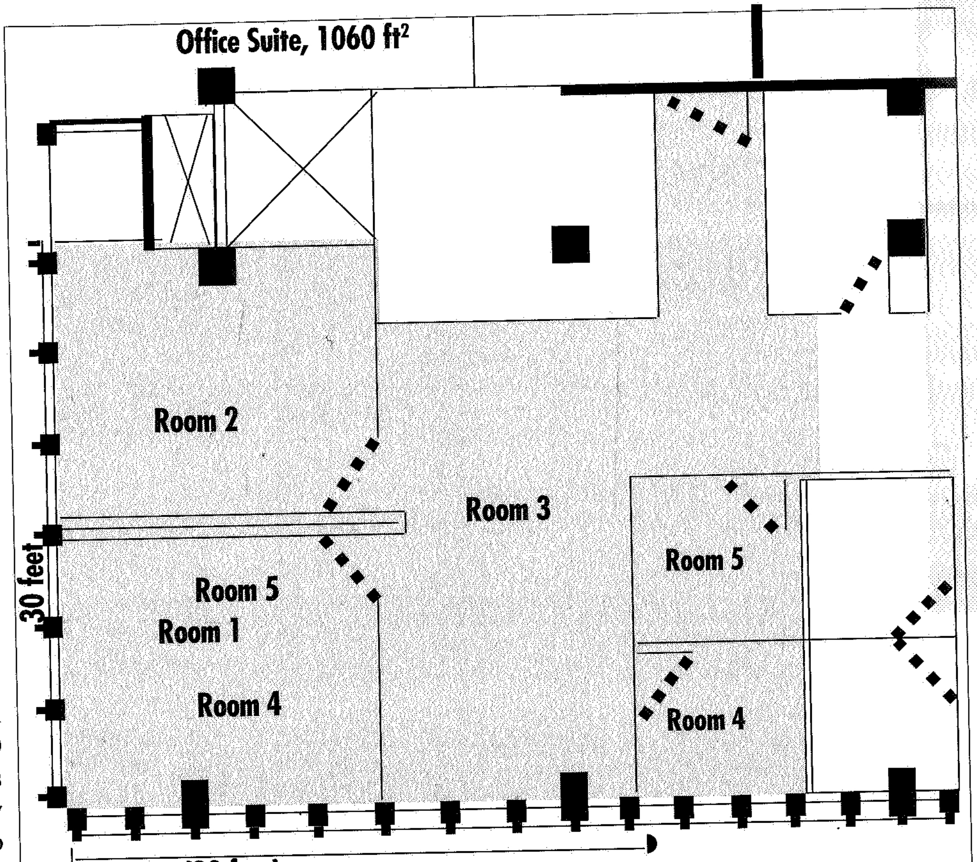

Figure 1— Diagram depicting test site.

Test Site

The test site consisted of a five-room vacant office suite encompassing 1,060 square feet (ft^2) (Figure 1). The site was located on the sixth floor of a 30-story building constructed in 1965-1966. No furnishings were present in the office suite. The suite consisted of a central room and four adjoining smaller offices. The ceiling system was composed of 2' x 4' lay-in mineral fiber tiles supported by a suspended T-bar grid. No asbestos was detected in three bulk samples of the ceiling tiles. The walls between each office were partitions which did not extend above the suspended ceiling. The distance from the suspended ceiling to the overhead deck was approximately 26 inches. The distance from the suspended ceiling to the bottom of the flanges of beams was approximately 11.5 inches and from the suspended tile ceiling to the floor was approximately 8.5 feet.

In preparation for the study, openings between the office suite and adjoining areas were sealed with 6-mil polyethylene sheeting. These included all heating, ventilation and air conditioning (HVAC) supply air diffusers in the ceiling and one wall mounted return air gill. The HVAC system did not use the ceiling space as an air plenum. The carpeted floor and two grass cloth wall coverings were covered with 6-mil polyethylene sheeting to prevent contamination of these materials. A two-chamber personnel decontamination unit was constructed at one entrance to the office suite.

The fireproofing had been spray applied to the beams and corrugated steel deck above the suspended tile ceiling. The fireproofing was friable and dust and debris was visible on the tops of ceiling tiles and light fixtures.

Study Design and Experiment Methods

Stationary air sampling was conducted before, during and after cable installation and cleaning activities. Personal sampling was conducted on two individuals during the cable installation and cleaning phases of the study. The study was designed to determine if there was a significant difference in airborne asbestos fiber concentrations resulting from the different activities or phases of the study. The phases were (1) before the work simulation, (2) during cable installation, (3) during cleaning, and (4) during a "die-down" period between installation and cleaning. A sufficiently large number of samples were collected so there would be a high probability of observing a statistically significant increase if the actual increase were 10-fold or greater.

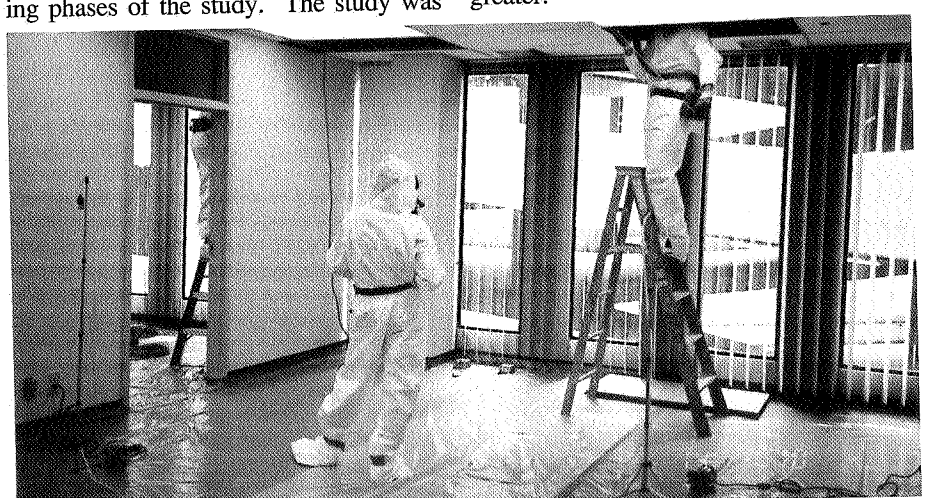
Figure 2— View of cable installation process from floor level.

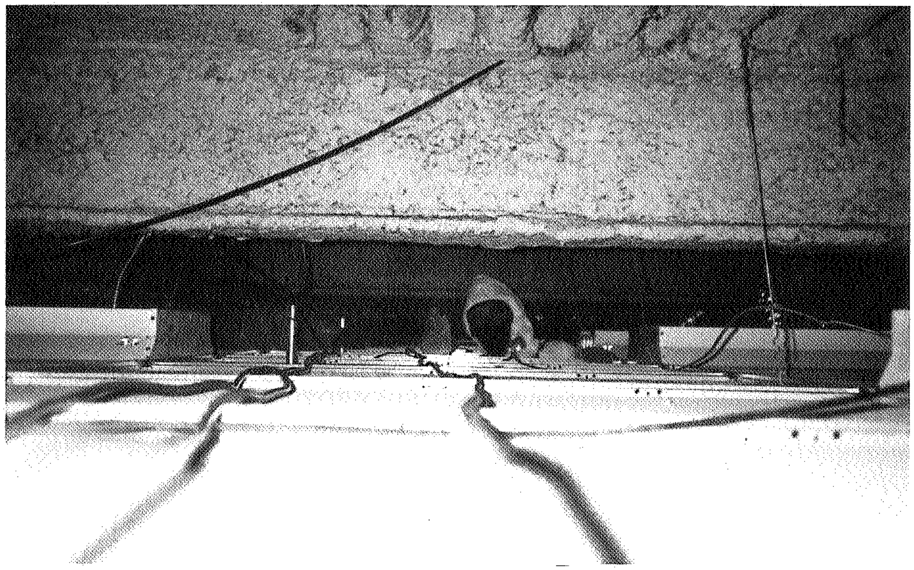

Figure 3— View of installed cables laying atop ceiling tiles with spray-applied fireproofing on the beam and deck above.

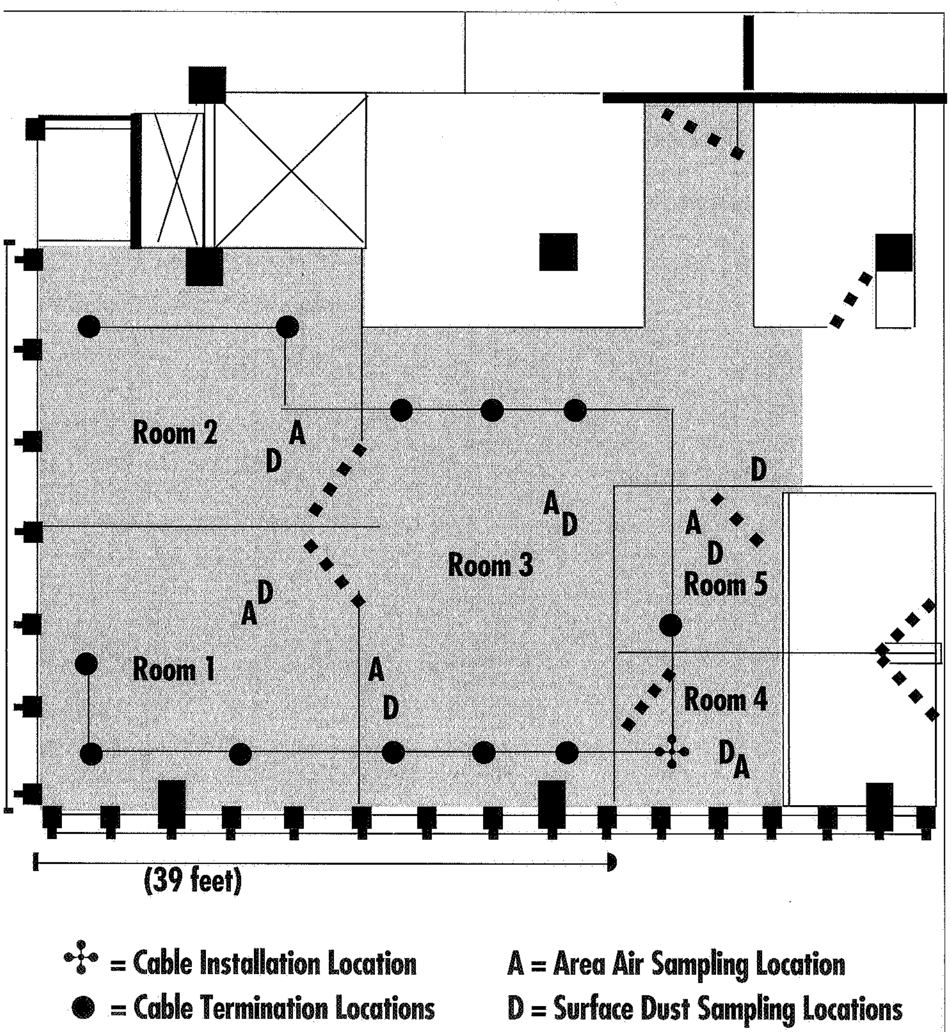

Figure 4— Diagram depicting cable routing and sampling locations.

Cable Installation Procedures

Twelve cables were cut to the desired length, labeled, coiled and placed in room 4 prior to beginning the study. Twelve cables would be sufficient to install twelve work stations. Number 16/3 electrical cord was used as the cable. The method of installing the cables was consistent with the method used in the electrical trade and with procedures used previously in the building. This method is referred to as the "throw and pull" method. A weight is attached to a string, which is attached to the cable, and is then thrown in the desired direction. The weight used was a one-inch steel nut.

One worker in room 4 threw the nut through the ceiling space to an open tile which was previously removed by a second worker. The second worker then pulled the string and attached cable to the opening. A typical throw was six to eight feet. The process was repeated as necessary for longer cable runs. The two individuals were instructed to avoid any direct contact with the fireproofing material and to avoid damaging the ceiling tiles or other building components to the extent possible. Figures 2 and 3 depict the cable installation process.

The installation of 12 cables required removal of 14 of the 134 ceiling tiles (10.4%) present in the office suite. Each tile was carefully removed from the ceiling grid, lowered to the floor, and stacked along the wall of each room. The location of each cable installation is shown on Figure 4.

The cable installation required 57 minutes to complete. The cables were then removed and the ceiling tiles replaced (26 minutes). Air sampling was only conducted during the installation phase since this was the specific activity of interest. A die-down period of 109 minutes followed with the resumption of area air sampling to serve as a baseline for comparison with the samples collected during the cleaning phase. Immediately following the die-down period, cleaning of the office suite was performed during a 30-minute period with area and personal air sampling conducted during this phase.

The routine cleaning consisted of two individuals sweeping the floor of each room with brooms, collecting any visible dust or debris in a dustpan, and depositing it into a labeled asbestos disposal bag. The few horizontal surfaces (e.g., door ledges) were wiped with a dry cotton cloth. Cleaning activities are depicted in Figure 5.

All participants in the study, including cable installers, clean-up personnel and observers wore air-purifying respirators and full-body protective clothing during all phases of the study. A two-chamber decontamination station employing a high efficiency particulate air (HEPA) filtered vacuum and wet cleaning was used for personnel and equipment exiting the work area. The HEPA filtered vacuum remained operating during the study to provide a slightly reduced pressure inside the work area with respect to surrounding areas.

Sampling and Analytical Methods

Area air sampling was conducted at stationary locations depicted on Figure 4. Additional area air sampling was conducted outside the office suite as a check for fiber migration. Personal sampling was conducted in the breathing zone of two individuals during the cable installation and cleaning activities. Area samples were collected using high-volume air sampling pumps at nominal flow rates of 10 liters per minute (8.9-10.1 lpm). Personal samples were collected using personal sampling pumps at nominal flow rates of 2 lpm (1.9-2.0 lpm). All air sampling pumps were calibrated before and after sampling using a Mini-Buck, model M-30 automated soap bubble calibrator. The sampling media consisted of a 0.45 micrometer (μm) pore size mixed cellulose ester (MCE) filter in a 25 mm sampling cassette as described in 40 CFR 763, Subpart E, Appendix A.[17]

Surface dust samples were collected from the floor (plastic covering on carpet) at locations shown on Figure 4. The locations coincided with the area air sampling locations. Surface sampling was performed following the cable installation and die-down period but before cleaning activities began. Surface sampling was performed using the microvacuum technique.[18] The surface collection area was 100 cm^2 for each sample. The sample was collected using a 0.45 μm MCE filter in a closed-face 25 mm diameter sampling cassette with a two-inch cowl. A 2.5 cm length of Tygon™ tubing cut with a serrated end was attached to the casette inlet. Flow rate through the cassette was maintained using a personal sampling pump calibrated at 2.0 lpm. The surface dust of each sampled area was collected by passing the nozzle across the sampling area twice for a total period of one minute.

At the conclusion of each air or dust sample, the sampling cassette was capped and sealed with tape. Four field blanks were collected and analyzed concurrent with the field samples. All samples were stored and hand-carried upright to the analytical laboratories. Six area air samples were typically collected during each phase of the study. Five from the six were randomly selected for TEM analysis. The remaining sample from each set was stored in case a sample was voided due to damage. No samples were voided. All personal samples and all surface dust samples collected after the cable installation were submitted for analysis. Each of the samples were analyzed using TEM with indirect preparation.

Figure 5—View of clean-up procedures with area air sampling pump at right.

The indirect preparation technique is preferred when comparing results from similar data sets.[19-20] The method has been previously described by Yamate, et al.[21] The relative merits of direct and indirect preparation techniques are still being debated. Nevertheless, it is apparent that the indirect preparation technique is particularly suited for experimental studies in which measured concentrations may vary over a wide range. Identification of asbestos structures was based on morphology, selected area electron diffraction (SAED), and energy dispersive X-ray analysis (EDXA). All asbestos structures that could be identified were counted.

Laboratory and field blanks were prepared and analyzed along with the samples. Twenty percent of the air samples analyzed by the primary laboratory were randomly selected for quality control (QC) analysis by a second laboratory.

Data Analysis

The geometric mean was used to represent the average or typical concentration of airborne asbestos fibers for each set of samples. Air pollution data have been shown to be lognormally distributed.[22] Accordingly, log transformation of the data results in a good approximation of a normal distribution and allows for the use of standard statistical tests. The mean of the log transformed data (geometric mean) is the appropriate measure of central tendency.

Analysis of variance was used to examine differences in the geometric means among the various phases of the study, with the Scheffé test used to determine the statistical significance of the observed differences.[23] The results are expressed as p values, with small values indicating low probabilities that the observed differences could have occurred by chance alone. A p value smaller than 0.05 is usually considered "statistically significant."

Presentation of Results

The results of all area and personal samples analyzed are summarized in Table I. The geometric mean asbestos concentration (area samples) before the study was

0.002 s/cm^3. During the cable installation period the mean concentration increased to 3.47 s/cm^3. The mean concentration for two personal samples collected on the installers was 26 s/cm^3. The geometric mean value for area samples collected during the die-down period following cable installation was 3.4 s/cm^3.

During cleaning of the office suite after the die-down period the geometric mean increased to 55 s/cm^3 as reflected by area samples. Personal samples collected during the same 30-minute cleaning period on the two individuals averaged 44 s/cm^3. The set of samples collected outside the office suite during cable installation and cleaning as a check for contamination, indicated a geometric mean of 0.004 s/cm^3.

The results of the comparison of geometric means are presented in Table II. These comparisons indicate a clear statistically significant increase during cable installation when compared to samples collected before the study began (p=<0.00005). In addition, a significant increase was found when cleaning activities were conducted after the die-down period (p=0.0023).

The arithmetic and geometric mean values for five settled dust samples taken from the floor surface following cable installation was 900,000 s/cm^2 and 190,000 s/cm^2, respectively. The difference between these means indicates a non-homogeneous deposition of dust across the floor surface. The settled dust represents an accumulation during the cable installation and die-down period phases of the study (192 minutes).

Analysis of the asbestos structures identified in 19 area and personal air samples indicated a composition of 58 % free fibers, 21% fiber bundles, 15% matrices, and 6% clusters. For all structures counted, 8% were greater than 5 micrometers in length.

The results of quality assurance comparisons for six samples analyzed by two laboratories indicated a Pearson correlation coefficient of 0.97. The quality control samples were selected in a stratified random fashion to capture a broad range of concentrations. In addition to being highly correlated, analyses of the six samples revealed good agreement in absolute terms and no pattern of higher values for either one of the laboratories. Most importantly, the conclusions of the study would have been the same regardless of which laboratory analyzed the samples.

Table I — Simulation of Cable Installation
Summary of Air Sampling Results

Phase	Arithmetic Mean (s/cm³)	Arithmetic Standard Deviation(s/cm³)	Geometric Mean (s/cm³)	Number of Observations
Before Installation	0.006	0.014	0.002	5
During Installation (Area Samples)	3.6	0.84	3.5	5
During Installation (Personal Samples)	26	7.5	26	2
Die-Down	3.8	1.9	3.4	5
Cleaning (Area Samples)	58	19.	55.	5
Cleaning (Personal Samples)	45.	7.9	44.	2
Background (Outside Worksite)	0.016	0.028	0.004	3

Table II — Simulation of Cable Installation
Comparison of Geometric Means (Scheffé Test)

Comparison [1]	Significance (p value)
Before vs. Installation	<0.00005
Before vs. Cleaning	<0.00005
Before vs. Die-Down	<0.00005
Before vs. Background	0.9630
Cleaning vs. Installation	0.0024
Cleaning vs. Die-Down	0.0023

[1]All other comparisons were not significant at the p=0.05 level.

Discussion

The results of this study involving a low-density fireproofing are similar to those obtained previously with a high-density fireproofing.[14] In each case, elevated airborne asbestos concentrations resulted from installing cable and the associated cleaning activities.

Accordingly, it may be concluded that cable installation involving traditional methods in the vicinity of asbestos-containing fireproofing can cause elevated asbestos exposures for those performing the task and others in the vicinity of the work.

This study was not designed to compare exposure levels to current or previous

OSHA permissible exposure limits (PELs). Furthermore, TEM and phase contrast microscopy (PCM) measurements are not directly comparable. However, some feeling for the likely magnitude of a concentration if it were measured by PCM can be obtained by considering only structures longer than 5 µm and wider than 0.25 µm. Using this approach, the personal samples collected in this study would have a PCM equivalent value in the range 0.5-2 f/cm^3 if no interfering fibers were present. However, since the fireproofing involved in this study contained 60 % mineral wool, PCM values would be a poor surrogate for actual asbestos exposure. The relationship between TEM and PCM measurements is discussed in detail in Chesson, Rench, Schultz and Milne (1990).[24]

Identifying the likely sources of exposure is important if exposures are to be controlled. During cable installation the primary source was asbestos-containing dust and debris on the top of 14 ceiling tiles removed to accommodate the maintenance activity. The secondary source was the in-place fireproofing itself. During the cleaning phase, the only significant source was the asbestos dust and debris on the floor and other horizontal surfaces within the office suite. Accordingly, control measures should focus on the asbestos-containing dust and prevention of its resuspension. For example, precleaning of ceiling tiles prior to removal should help reduce exposures. Further research is clearly needed in this area to evaluate alternative control techniques and work practices.

These data suggest that cable installers and custodians have in the past experienced episodic exposures such as these demonstrated. Several articles in the literature have demonstrated an increase in asbestos-related disease among building service workers, maintenance personnel, and custodians.[7-9,25-26] To date, however, little information is available regarding asbestos related disease among communication workers and electricians.[27] The need exists to characterize past exposure to these population groups and through epidemeological investigation determine to what extent these groups are at risk of developing an asbestos related disease.

Studies of this type further demonstrate the need to evaluate the sampling and analytical protocols to measure episodic exposures. For example, should phase contrast microscopy be used to measure airborne asbestos with its inherent inability to distinguish between asbestos and nonasbestos fibers or to resolve fibers thinner than 0.25 µm and (based on current PCM counting procedures) shorter than 5 µm? To do so would eliminate approximately 90 % or more of the asbestos fibers available for exposure from consideration and permit interfering fibers (cellulose, mineral wool, synthetic fibers) to further cloud the results.[28-30]

Dust sampling provides useful information for designing measures to reduce exposures. Air sampling can only document the presence of asbestos in the air. It cannot detect potential sources of airborne asbestos such as dust. Surface dust sampling permits sources of asbestos available for reentrainment to be pinpointed and remedial measures taken before the actual exposure occurs. Further research is still necessary to standardize dust and air sampling techniques, including the number of samples necessary to characterize a given surface area, recovery efficiency from various surfaces,

Table III — Area and Personal Sampling Results

Sample Number	Description	Concentration (s/cm^3)*
1002	Before Cable Installation, Room 1	<0.016
1003	Before Cable Installation, Room 2	<0.016
1004	Before Cable Installation, Room 3	<0.016
1005	Before Cable Installation, Room 5	0.032
1006	Before Cable Installation, Room 4	<0.016
1007	Cable Installation, Room 4	3.9
1008	Cable Installation, Room 1	3.6
1010	Cable Installation, Room 2	2.2
1011	Cable Installation, Room 3 (South)	4.5
1012	Cable Installation, Room 3 (North)	3.6
1017	Personal Sample, Feeding Cable	32.
1018	Personal Sample, Receiving Cable	21.
1021	Die-Down Period, Room 5	5.1
1022	Die-Down Period, Room 3 (South)	2.0
1023	Die-Down Period, Room 2	1.9
1024	Die-Down Period, Room 3 (North)	4.0
1025	Die-Down Period, Room 1	6.2
1026	Cleaning, Room 5	57.
1027	Cleaning, Room 3 (North)	68.
1028	Cleaning, Room 3 (South)	80.
1029	Cleaning, Room 4	51.
1031	Cleaning, Room 2	30.
1033	Personal Sample, Cleaning	39.
1034	Personal Sample, Cleaning	50.
1014	Perimeter Sample, Outside Test Site During Cable Installation and Cleaning	<0.024
1015	Perimeter Sample, Outside Test Site During Cable Installation and Cleaning	<0.026
1016	Perimeter Sample, Outside Test Site During Cable Installation and Cleaning	0.049

*Results include all structures detected. Chrystotile was the only form of asbestos found.

and the analytical technique employed when heavy concentrations of asbestos and other particles are encountered.

ACKNOWLEDGMENT

This study was funded, in part, by the Plaintiff's Executive Committee of the National School Asbestos Class Action. The authors retained full control over the design and execution of the study, and the interpretation and reporting of the results. The authors are grateful to Bonnie Bonham for her work in preparing the manuscript.

REFERENCES

1) U.S. EPA Office of Pesticides and Toxic Substances: *Guidance for Controlling Asbestos-Containing Materials in Buildings.* USEPA Pub. No. 560/5-85-024, Washington, D.C. (1985).

2) Lory, E.E., D.S. Coin: Technical Report R883, "Management Procedure for Assessment of Friable Asbestos Insulating Material. Civil Engineering Laboratory," Naval Construction Battalion Center, Port Hueneme, CA (1981).

3) Selikoff, I.J.: The Third Wave of Asbestos Disease: Exposure to Asbestos In Place. Andrews Communications, Inc., New York (1990).

4) Department of the Environment: Asbestos Materials in Buildings, 2nd Edition. Her Majesty's Stationary Office, London, U.K. (1986).

5) *Managing Asbestos in Place, A Building Owner's Guide to Operations and Maintenance Programs for Asbestos-Containing Materials.* USEPA Pub. No. 20T-2003, Washington, DC (1990).

6) Millette, J.R., W.M. Ewing, R. Brown, "Stepping on Asbestos Debris." *Microscope*, pp. 321-326 (1990).

7) Oliver, L.C., N.L. Sprince, R. Greene: "Asbestos-Related Disease in Public School Custodians." *Am. J. Ind. Med.* 19:303-316 (1991).

8) Huncharek, M., J. Muscat, J. Capotorto, Pleural Mesothelioma in a Lift Mechanic. *Br. J. Ind. Med.* 46:500-501 (1989).

9) Stein, R.C., J.Y. Kitajewska , J.B. Kirkham, N. Tait, G. Sinha, R.M. Rudd: Pleural Mesothelioma Resulting from Exposure to Amosite Asbestos in a Building. *Resp. Med.* 83:237-239 (1989).

10) Litzistorf, G., M.P. Guillemin, P. Buffat, F. Iselin : Influence of Human Activity on the Airborne Fiber Level in Paraoccupational Environments. *J. Air Poll. Control Assoc.* 35(8):836-337 (1985).

11) Paik, N.W., R.J. Walcott, P.A.Brogan: Worker Exposure to Asbestos During Removal of Sprayed Material and Renovation Activity in Buildings Containing Sprayed Material. *Am. Ind. Hyg. Assoc.* J. 44(6):428-432 (1983).

12) Sawyer, R.N.: Asbestos Exposure in a Yale Building. *Environ. Res.* 13:146-169 (1977).

13) Crandlemere, R.W., D. Azrael, M.S. Evans, S. Brown: PCM and TEM Evaluation of Disturbance Testing of Asbestos "Popcorn" Type Acoustical Ceilings. *Nat. Asbestos Council J.* 7(2): 47-51.

14) Keyes, D.L., J. Chesson, W.M. Ewing, et al.: Exposure to Airborne Asbestos Associated with Installing Cable Above a Suspended Ceiling. *Amer. Ind. Hyg. J.* 52(11):479-484 (1991).

15) Keyes, D.L., J. Chesson.: "Summary of A Study of Asbestos Exposure During Cleaning Activities." Paper presented at the National Asbestos Council Conference, San Antonio, Texas (1990).

16) Kominsky, J.R., R.W. Freyberg, J. Chesson: Evaluation of Two Cleaning Methods for the Removal of Asbestos Fibers From Carpet. *Am. Ind. Hyg. Assoc. J.* 51(9):500-504 (1990).

17) U.S. EPA, 40 CFR Part 763, Asbestos-Containing Materials in Schools, Final Rule and Notice. *Federal Register* 52(210):41825-41905.

18) Millette, J.R., T. Kremer, R.K. Wheeles: "Settled Dust Analysis Used in Assessment of Buildings Containing Asbestos." *Microscope* 38:215-220 (1990).

19) Sebastian, P.: "Direct or Indirect Microscope Methods for Measuring Asbestos Air Pollution in the Environment." Paper presented at the American Industrial Hygiene Conference in Orlando, Florida (1990).

20) U.S. EPA Office of Pesticides and Toxic Substances: *Comparison of Airborne Asbestos Levels Determined by Transmission Electron Microscopy (TEM) Using Direct and Indirect Transfer Techniques.* U.S. EPA Pub. No. 560/5-89-004, Washington, DC (1990).

21) Yamate, G., S.C. Agarwal, R.D. Gibbons: *Methodology for the Measurement of Airborne Asbestos by Electron Microscopy.* U.S.EPA Office of Research and Development (1984).

22) Gilbert, R.O.: "Statistical Methods for Environmental Pollution Monitoring." Van Nostrand Reinhold, New York, p. 152 (1987).

23) Miller, R.G.: "Simultaneous Statistical Inference." Springer-Verlag, New York (1981).

24) Chesson, J., J.D. Rench, B.D. Schultz, K.L. Milne, M. Lacker, E. Holstein , R. Lilis., E. Crucker: Interpretation of Airborne Asbestos Measurements. *Risk Analysis* 10(3):437-447 (1990).

25) Michaels, D., S. Zoloth: "Asbestos Disease in Sheet Metal Workers: II. Radiologic Signs of Asbestosis Among Active Workers." *Am. J. Ind. Med.* 12:595-603 (1987).

26) Michaels, D., S. Zoloth: "Asbestos Disease in Sheet Metal Workers: Proportional Mortality Update." *Am. J. Ind. Med* 13:731-734 (1988).

27) Huncharek, M., J. Muscat: "Pleural Mesothelioma in a Non-Shipyard Electrician." *Br. J. Ind. Med.* 47:68 (1990).

28) Guillemin, M.P, P. Madelaine, G. Litzistorf, P. Buffat, F. Iselin: "Asbestos in Buildings, The Difficulties of Reliable Exposure Assessment." *Aeros. Sci. Tech.* 11:221-243 (1989).

29) Dement, J.M., K.M. Wallingford: "Comparison of Phase Contrast and Electron Microscopic Methods for Evaluation of Occupational Asbestos Exposures." *Appl. Occup. Environ. Hyg.* 5(4):242-247 (1990).

30) Willeke, K., P.A. Baron: "Sampling and Interpretation Errors in Aerosol Monitoring." *Am. Ind. Hyg. J.* 51(3):160-168 (1990).

AUTHOR AFFILIATIONS

[A] *Diagnostic Environmental, Inc., 350 Franklin Road, Suite 300, Marietta Ga. 30067*

[B] *Chesson Consulting, Inc., 1717 Massachusetts Ave. NW, Suite 601, Washington, D.C. (Present Address: Resource Assessment Commission, Fisheries Resources Branch, Bureau of Resource Sciences, P.O. Box E11, Queen Victoria Terrace, Canberra ACT 2600, Australia.)*

[C] *Law Engineering, Inc., 396 Plasters Ave., N.E., Atlanta, Ga. 30024.*

[D] *Gobbell Hays Partners, Inc., 217 Fifth Ave. North, Nashville, Tenn. 37219.*

[E] *Environmental Sciences, Inc., 105 East Speedway Blvd., Tucson, Ariz. 85705.*

[F] *Materials Analytical Services, Inc., 3597 Parkway Lane, Suite 250, Norcross, Ga. 30092.*

[G] *MVA, Inc., 5500 Oakbrook Pkwy., Suite 200, Norcross, Ga. 30093.*